II.—*The Faults and Foldings of the Pictou Coal Field.*

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This coal field is comparatively limited in extent, being eight miles long and three and a half miles wide, and presents the shape of a pear wtih its stem pointing to the east.[1] In it, however, are exhibited on an unusual scale three of the great features of geology: a development of large seams of coal, a system of immense faults, and an equal measure of denudation.

The first is shown by the presence of a number of seams exceeding ten feet in thickness—one, the Albion Main seam, being thirty-nine feet thick. The faults equal in magnitude the thickness of the sediments of the district, which the late Sir William Logan estimated at 5,567 feet. The denudation has been on an equally extensive scale.

The district having its greatest length in an east and west direction, is bisected by the East River. In the western division, the lower half of the productive measures outcrop, and extending across the river into the eastern division, are there covered by the upper group. The general arrangement of the measures is that of a main east and west synclinal, modified by transverse foldings at each end, giving rise to subordinate but almost independent basins. There is also a subordinate synclinal lying south of the main fold; and in the succeeding millstone grit, two more synclinals have been noticed.

However vain conjecture may be as to the former extent of this coal field, enough can be deduced from its present position and extent to warrant the presumption that it is now but a fragment. Taking the western division, the strata are folded in a synclinal two miles wide, the northern edge dipping at an angle of about eighteen degrees, and the lower beds turn over into the subordinate synclinal referred to above. This section, recalling in its regularity the typical examples given in geological text-books, undoubtedly extended at one time to the full limit of the minor synclinal. Taking in a similar manner the eastern division with a total thickness of 5,000 feet, there would be presented, on a reduction to sea level, a mass towering high above any mountain of the Lower Provinces, and as nature never formed coal fields as this one is now presented between bounding faults, like layers in a chest, it is evident that formerly the coal field must have had greatly enlarged limits. These remarks, referring more particularly to the southward extension of the coal field, are equally applicable to its northern outcrop.

Immediately to the north of the coal field with its upturned edge, comes an immense mass of conglomerate, referred by the officers of the Geological Survey to the top of the

[1] Reference may be made to the map of the Pictou Coal Field. Geo. Sur. Rep. 1869.

millstone grit, from the debris of which it is chiefly formed, and dipping to the north, at an angle of about thirty degrees. It presents its basset edge to the coal field in a long steep ridge. Borne up on its crest are measures, lying conformably on it, which, gradually lessening in dip, are repeated in gentle undulations until they pass under the Gulf of St. Lawrence. They represent strata succeeding the productive measures, the lower portion, resting on the conglomerate, being possibly representative of the highest beds of the coal field as now known, or of the sequence immediately following them. These measures show no signs of the great faulting and folding to which the coal measures have been subjected, and presumably these movements took place at or near the close of the deposition of the productive coal-bearing strata. It may be remarked that the consolidation of the millstone grit must have been followed by changes of level permitting the accumulation of the immense mass of the conglomerate referred to above, in places 1,600 feet thick.

Presumably, therefore, an ideal restoration of the coal field would present it extending not only far to the south, but also some distance north of the village of New Glasgow, standing on its northern edge. This portion, now isolated by the protrusion of the conglomerate, possibly exists in a northern basin lying between New Glasgow and Pictou. The consideration of this point is more speculative than practical, for whatever productive measures may exist there, they are deeply covered by the mantle of later Carboniferous and Permo-Carboniferous, with its southern skirt resting directly on the conglomerate.

It is suggested that the coal field formerly extended westward, but was covered by newer strata, as to the north of New Glasgow; but the grounds for assuming any great extension toward the east are not apparent. If the magnitude of the coal beds be any measure of the extent of the district in which they were formed, this must once have rivalled the largest coal field now known.

Regarding for a moment the boundary faults which have "let down" this patch of coal measures among millstone grit and Pre-Carboniferous, there is presented an immense mass of strata, planed away, until now there is but the usual rolling country of the Lower Provinces, which little shows the force which lifted some 5,000 feet of strata into swelling hills, and marked its way with faults of equal magnitude. Was this wasting mass of sediments carried to the south or to the north? If in the former direction, it must have moved beyond our observation into the Atlantic, or succeeding forces have swept its debris from the Silurian and Cambro-Silurian ledges now outcropping everywhere between it and the southern shores of the province. Possibly its ruins contributed to the later formations lying to the north of New Glasgow, and the drainage was in the same direction as in the present day. From the report of Mr. Fletcher, of the Geological Survey, on the Island of Cape Breton, it would appear that there, from the singular manner in which the Carboniferous run up the glens of the St. Ann's and Baddeck Rivers the drainage was then in the same direction and through the same channels as at the present day. In more recent times the East River and its tributaries have worn away the strata until the coal measures lie as a valley between the Pre-Carboniferous on the south and the millstone grit on the north.

The "boundary" faults of the district already alluded to consist essentially of one running east and west between the conglomerate and the coal measures, and bringing the upper beds of the latter into contact with the various divisions of the former, and with Pre-Carboniferous strata. A parallel fault brings up millstone grit, Lower Carboni-

ferous, and Pre-Carboniferous, on the south side. Faults less sharply defined, for reasons to be given further on, mark the eastern and western boundaries of the district.

The coal fields of Nova Scotia, equally with those of Pennsylvania, bear witness to the disturbances marking the close of the Carboniferous of eastern America. Dana remarks that the force producing the Appalachian foldings acted at right angles to the courses of flexures, therefore, to the general course of the Atlantic; that it acted from the ocean, and that it was slow in action and long continued. In the district under consideration, equally as in those of Cumberland and Cape Breton, the force was at right angles to the shore, and the flexures may be regarded as the north-easterly prolongations of those referred to by him. In his remarks, he dwells upon the fact that all the Palæozoic were included in the grand scheme of folding.

In Nova Scotia, however, two systems at least of folding are clearly noted. The Silurian and Cambro-Silurian measures were folded into massive east and west anticlinals, having a general course closely corresponding to that of the coast, and remarkably parallel to each other. This folding gave rise to numerous fissures parallel to the strata, which were filled with quartz, frequently auriferous. Speaking in general terms, the folding preceded the filling of the veins with quartz, and this again preceded the Carboniferous, as the lower beds of this formation, when they rest on the auriferous slates, are known to carry free gold. The exact date can be fixed only by assuming that the intrusive masses of granite, which are older also by similar proof than the Carboniferous, and penetrate Oriskany sandstones, are, in addition, connected in rough contemporaneity with the foldings carrying auriferous veins, in the neighbourhood of which they frequently occur.

In the present connection, this point is of interest chiefly as showing that older forces acted on the Pre-Carboniferous rocks in a similar manner with regular foldings, great faults, and immense denudation beginning prior to the Carboniferous, and continuing to the present day.

The following list, taken from surveys made by the Department of Mines to ascertain the general course of these auriferous anticlinals, in order that the mining areas might run fairly on the courses of the strata veins, shows this striking regularity :—

Sherbrooke	E & W,
Fifteen Mile Stream	S 80° E,
Beaver Dam	S 57° E,
Tangier	E & W,
Caribou	N 87° E,
Jennings	N 74° E,
Chezetcook	N 75° E,
Lawrencetown	S 87° E,
Waverley	N 81° E,
Oldham	N 82° E.

Were the Carboniferous horizons of Nova Scotia superimposed with only local unconformity upon the lower members of the Palæozoic series, any folding force would produce regular flexures pushed, perhaps, in places to the extent of overturn dips, as actually took place in some of the older foldings referred to above. This was not the case, as these measures succeeded with marked and complete unconformability.

If the force alluded to by Dana be applied under the conditions afforded by the hardened and irregular outlines of the folded slates and quartzites, stiffened by masses

of granite, all intervening between the Atlantic and the Carboniferous lying to the north, and along the gulf of St. Lawrence, and also underlying them, different results would appear. The more plastic and regular strata would be subjected to the movements of a comparatively rigid body. Therefore, in addition to the general east and west folds, there are met transverse flexures and local undulations, which can in some cases be referred to projecting ridges of the older strata, or to their undulations extending under the carboniferous.

In the case of the Pictou coal field, as the folding proceeded, it was limited by the outlines of the subjacent and boundary rocks older in age; and the more yielding measures, the Carboniferous, were bent and fractured according to the varied position of these outlines. The longer the folding continued, the more marked the fracture, which resulted in each underlying ridge of older measures coming finally into contract with the upper beds of the productive strata.

Thus the coal measures at one point in the south side come directly against McLellan's Mountain, and similarily on the north side against Waters Hill, both Pre-Carboniferous ridges. While at either end of these once hidden hill tops, the prolongation of the fractures along the foldings merely bring the various Carboniferous horizons into unconformability. Similar examples of this are seen at Mabou, and Cape Dauphin, in Cape Breton, where the Pre-Cambrian come into close relationship with the coal measures, while a short distance away, the foldings and the faults of elevation intermix only the carboniferous subdivisions.

In the Pictou district there are, as has been already mentioned, transverse foldings. It may be noticed that when the east and west foldings had attained approximately their present attitude, and when by degrees the tension had been relieved by the succession of faultings which are now practically represented as a fault bounding the coal field on the south as well as on the north, the subordinate transverse foldings would arise from a further continuance of the movement. Then the more prominent spurs and ridges of the Pre-Carboniferous would inflict, on the superimposed strata, elevations giving rise to subordinate transverse folds. Thus in this district the points of maximum elevation of these foldings are found opposite the Pre-Carboniferous of McLellan's and Waters Hills.

The south and north edges, therefore, of the Pictou main synclinal, are marked by the series of faultings which bring lower measures up abreast of the productive; the continuation of the movement produced, along the line of deep buried ridges or spurs, transverse foldings which made their mark when the once great and solid mass of sediments had been divided into longitudinal masses.

The practical application of these principles to the business of the miner becomes evident when it is considered that almost all faults result from foldings such as the Pictou district exhibits in a typical form. The east and west faults are those connected directly with the main foldings, while those running transversely are caused by the subordinate elevations, or are the resultant of the variations of the main folds from straight lines, owing to spurs of the older rocks projecting under the Carboniferous.

Thus in the western district, the main synclinal axis dips eastwardly until a point is reached about a mile west of the East River; here it reverses and dips to the west, forming what is turned by the miners a "saddle." The coal has been worked extensively near the line of the axis, and there are met, at intervals of from five to twenty chains, "up-throws,"

going west, of from five to thirty feet, culminating at the "saddle" in one of about fifty feet. These faults in some instances do not extend far from the axial line.

Taking those faults of the second class resulting from irregularities of the main folding, they are usually oblique to its general course, and radiate from some point marking an interruption to the regular flexure. Such faults are not unfrequently small towards the outcrop, and after attaining their maximum throw, diminish again, or present themselves as a series of small faults accompanied by irregularities in the seam, and changes of dip.

The practical importance to miners of a general knowledge of the structure of the district they are operating in, should be more generally recognised than is usually the case. Faults are encountered necessarily as part of the hazard of every mining enterprise, but too frequently they are attacked with equal chance. The study of the extent of the folding and uplifting forces, gives a clue to the dislocations marking their course, and when once a fault is recognised as belonging to any fixed system, the next one opposing the miner can be overcome with less labor.

It need not be inferred from these remarks that the faults occurring in coal mines always approach the vertical in their "underlie." Cases are noted where the pressure appears to have taken an almost horizontal direction, as if the overlying measures had been too thick or too loose to have all participated in the movement. Under these conditions, the first result of the pressure is seen in one or more undulations of the coal bed with a thinning of the seam, but no interruption of its continuity. A more continued pressure gives rise to what are known as "dirt faults," in which the seam is slightly displaced and its contents broken and crushed. If the pressure be more abrupt, a flat lying fault is the result, which sometimes presents the reverse of the miner's rules, which are based upon the generally correct assumption, that the inclination of the plane of fracture points to the position of the disrupted portion of the seam.

Cases have been noticed where the pressure, acting through one or more beds of sandstone harder and less yielding than the associated strata, has forced them obliquely against a coal seam so as either to practically obliterate the seam over a considerable width of ground, or to move it with a more or less defined fracture above its level, from which point the seam gradually returns to its normal level and water course.

This system of faulting is generally observed in seams lying at low angles. In those more steeply inclined, especially where transverse foldings have taken place, they are represented usually under two heads. Where the measures are hard and unyielding, the seam is broken and confused for some distance; but where they are soft, as in the presence of shales, etc., a series of undulations compressing the coal into lenses are observed. The compressed coal is frequently hardened, derived of more or less of its volatile matter, and retains few marks of its original lamination.

From a consideration of the effects referred to in these notes as producing dislocations, it may be gathered that, in any given locality, a fault may not exceed the length of the flexure producing it, and must frequently be much shorter. The bearing of this on the study of the structure of a district by a field geologist should always be borne in mind. Deductions based on the prolongations of any transverse fracture are uncertain; the lines following the main flexures are, on the contrary, important clues in questions of unconformably succeeding horizons.

The data referring to faults in all districts should be carefully preserved, and as far as practicable noted on geological maps. The writer having necessarily had his attention directed to these misfortunes of the miner, and having seen time and money fruitlessly spent in overcoming them, believes that the honorable members of this Section of the Royal Society could best elaborate the points raised in these brief notes and furnish material for their more satisfactory solution.